File Ref.No.8957/GA - IV - J1/2012/CU

UNIVERSITY OF CALICUT

Abstract

General and Academic -Faculty of Science -Revised Scheme and Syllabus of M.Tech Nanoscience and Technology Programme w.e.f 2021 Admission onwards (University Teaching Department) -Incorporating Outcome Based Education- Implemented - Subject to ratification by Academic Council -Orders Issued.

G & A - IV - J

U.O.No. 5491/2021/Admn Dated, Calicut University.P.O, 22.05.2021

Read:-1. U.O.No. 14707/2019/Admn dated, 18.10.2019

2. Item No.1 of the Minutes of the meeting of the Board of Studies in Nanoscience and Technology held on 29.03.2021.
3. Remarks of the Dean Faculty of Humanities, Dated 17.05.2021.
4. Orders of the Vice chancellor in the file of even no, Dated 22.05.2021.

ORDER

1. The scheme and syllabus of M.Tech Nanoscience and Technology Programme under CCSS PG Regulations 2019, w.e.f 2019 admission onwards for University Teaching Departments has been implemented in the University, vide paper read (1) above.
2. The meeting of the Board of Studies in Nanoscience and Technology (SB), held on 29.03.2021, vide paper read (2) above, has resolved to approve the revised Syllabus of M.Tech Nanoscience and Technology Programme incorporating Outcome Based Education (OBE) w.e.f. 2021 admission onwards.
3. The Dean, Faculty of Science, vide paper read (3) above, has approved the above resolution of the Board of Studies in Nanoscience and Technology (SB) held on 29.03.2021.
4. Considering the urgency, sanction has been accorded by the Vice Chancellor, to implement the revised syllabus of M.Tech Nanoscience and Technology Programme incorporating Outcome Based Education, in tune with CCSS PG Regulations 2019 , vide paper read (4) above, subject to ratification by the Academic Council.
5. The Revised scheme and syllabus of M.Tech Nanoscience and Technology Programme, in tune with CCSS PG Regulations 2019, incorporating Outcome Based Education (OBE), is therefore implemented with effect from 2021 Admission onwards, subject to ratification by the Academic Council.
6. Orders are issued accordingly. (Syllabus appended).

Arsad M

Assistant Registrar

To

The Head, Department of Nanoscience & Technology

Copy to: PS to VC/PA to PVC/ PA to R/PA to CE/JCEI, VII/CHMK Library/Information Centres

Forwarded / By Order

Section Officer

MTECH NANOSCIENCE AND TECHNOLOGY

Program Code - NST-01

CURRICULUM & SYLLABI

2021 Admission onwards

UNIVERSITY OF CALICUT

(A State University Accredited with "A" Grade by NAAC)

Calicut University P.O., Kerala, 673635, INDIA

Ph: 0494 2407373, 2407374, *Email*: nanohod@uoc.ac.in

www.universityofcalicut.info, https://nanotechnology.uoc.ac.in

April 2021

Program *Educational Objectives (PEOs)*

MTech Nanoscience and Technology program is designed to provide the students suitable environment and facilities for molding them into experts in their corresponding fields. The major objective of this program is to improve the knowledge skills and attitudes of the students to meet the growing need of qualified experts to work in this area.

PEO-1	To bring students from different branches of Science and Engineering under one roof to get benefits of each other's to develop a purely multidisciplinary group to work in the area of applied research focusing the science and technology close to nano regime
PEO-2	Facilitate the students to develop research attitude to do innovative research in diverse area of Nanoscience and Technology
PEO-3	Facilitate research ambiance and practical experiences with advanced technologies for the understanding of exceptional properties shown by matter at nanoscale
PEO-4	Train the student to design a research problem and the selection of methodologies for meeting the fixed objectives to solve the problem.
PEO-5	To improve the knowledge skills and attitudes of the students to meet the growing need of qualified experts to work in this area.

Program *Specific Outcomes (PS*Os)	
PSO-1	The basic understanding of how interdisciplinary science works to coordinate Nanoscience and Technology.
PSO-2	The vital awareness of computational/mathematical programs to solve the bottleneck issues in different aspects of science and technology.
PSO-3	Excellent exposure to different spectroscopic and microscopic techniques while studying all the possible nanosystems in detail.
PSO-4	New ideas to develop advanced nanomaterials for sustainable/eco-friendly energy, clean water, pollution-free air, and modern biology.
PSO-5	Well-tempered professional ethics essential to maintain a transparent career.

Program *Outcomes (P*Os)	
PO-1	Illustrate fundamental concepts of size and shape dependent changes in the properties of nanostructured materials for multifunctional applications.
PO-2	Demonstrate the ability to synthesize and characterize nanostructured materials.
PO-3	Demonstrate ability to design new nanostructured materials, characterize, interpret and analyze the data for catering the needs of the industry.
PO-4	Demonstrate new ideas for addressing the problems of societal relevance such as energy crisis, environmental remediation and medicine using the knowledge gained through specific electives.
PO-5	Develop confidence in self-educating new knowledge and gain the ability for life-long learning.

UNIVERSITY OF CALICUT; KERALA: 673635

MTech Nanoscience and Technology Curriculum (University Department)

(For the students admitted during 2021-2022 onwards)

SI. No.	Course Code	Course Title	Credits	Hours/Week		Max. Marks		
				Theory	Practical	Int.	Ext.	Total
FIRST SEMESTER								
1	NST.101	Quantum Mechanics	4	4	0	40	60	100
2	NST.102	Structure and Bonding in Solids	4	4	0	40	60	100
3	NST.103	Computational Methods &Data Processing	4	4	0	40	60	100
4	NST.104	Introduction to Nanomaterials	4	4	0	40	60	100
5	NST.105	Nano Lab – 1	4	0	6	40	60	100
		Total	**20**	**16**	**6**	**-**	**-**	**500**
6	NST.106	Ability Enhancement Course (AEC)	Audit Course with 2 credits* (2 hours per week)					

***** Credit of this course (NST.106) will not be considered while calculating the SGPA/CGPA

SI. No.	Course Code	Course Title	Credits	Hours/Week		Max. Marks		
				Theory	Practical	Int.	Ext.	Total
SECOND SEMESTER								
1	NST.201	Design and Synthesis of Nanomaterials	4	4	0	40	60	100
2	NST.202	Characterization Techniques of Nanomaterials	4	4	0	40	60	100
3	NST.203	Bio- Nanomaterials	4	4	0	40	60	100
4	NST.204	Properties and Applications of Nanomaterials	4	4	0	40	60	100
5	NST.205	Nano Lab-II	4	0	6	40	60	100
		Total	**20**	**16**	**6**	**-**	**-**	**500**
6	NST.206	Professional Competency Course (PCC)	Audit Course with 2 credits*(2 hours per week)					

***** Credit of this course (NST.206) will not be considered while calculating the SGPA/CGPA

SI. No.	Course Code	Course Title	Credits	Hours/Week		Max. Marks		
				Theory	Practical	Int.	Ext.	Total
THIRD SEMESTER								
1	NST.301	Advanced Nanomaterials	4	4	0	40	60	100
2	NST.302	Computational Nanotechnology	4	4	0	40	60	100
3	NST.303	Societal and Environmental Impact of Nanotechnology	2	2	0	40	60	100
4	NST.304	ELECTIVE	4	4	0	40	60	100
5	NST.305	Mini Project	6	0	9	40	60	100
		Total	**20**	**14**	**9**	**-**	**-**	**500**

SI. No.	Course Code	Course Title	Credits	Hours/Week		Max. Marks		
				Theory	Practical	Int.	Ext.	Total
FOURTH SEMESTER								
1	NST.401	Major Project	20	0	30	40	60	100
		Total	**20**	**0**	**30**	**-**	**-**	**100**

PROGRAM TOTAL CREDITS (SEM-I + SEM-II+ SEM-III+ SEM IV) = 80 Credits

****

SI. No.	Course Code	Course Title	Credits	Hours/Week		Max. Marks		
				Theory	Practical	Int.	Ext.	Total
ELECTIVE PAPERS								
1	NST.304-A	Nanomaterials for Energy Conversion and Storage	4	4	0	40	60	100
2	NST.304-B	Advanced Spectroscopy and Microscopy	4	4	0	40	60	100
3	NST.304-C	Nanomaterials for Photocatalysis and Solar Fuel Generation	4	4	0	40	60	100
4	NST.304-D	Micro/Nano Electro-mechanical Systems (MEMS/NEMS)	4	4	0	40	60	100
5	NST.304-E	Sustainable Nanomaterials	4	4	0	40	60	100

FIRST SEMESTER

Course Code	NST.101	QUANTUM MECHANICS	L	T	P	C
Core			4	0	0	4
Pre-requisite	Basic knowledge in general physics, Chemistry and mathematics.		Syllabus Version		2021-2022	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Understand the fundamental concepts and principles in quantum mechanics for different systems.
2. Learn the method of solving problems quantum mechanically.
3. Understand the concepts of statistical mechanics.
4. Learn the method of evaluation of kinetics and thermodynamics of chemical reactions.

Course Outcomes

1. Recall the reasons for the failure of Classical Mechanics – K1
2. Understand quantum mechanics of small systems – K2
3. Understand different types of statistical methods – K2
4. Apply quantum mechanical concepts for the evaluation of rate equations in small systems – K3, K5

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Quantum Mechanics of different systems	20 Hours

Introduction to Quantum mechanics. Postulates of quantum mechanics. Quantum mechanics of translational motion- particle in 1D and 3D box. Tunneling. Quantum mechanics of vibrational motion- One-dimensional harmonic oscillator. Quantum mechanics of rotational motion- Rigid rotator. Spherical harmonics. Quantization of angular momentum, quantum mechanical operators corresponding to angular momenta ((Lx, Ly, Lz), commutation relations between these operators.

UNIT-II	Quantum Mechanics of Hydrogen-like Atoms	15 hours

Potential energy of hydrogen-like systems, the wave equation in spherical polar coordinates, separation of variables, the R, Theta and Phi equations and their solutions. Orbitals, radial functions and radial distribution functions and their plots, angular functions (spherical harmonics) and their plots. Spin-postulate-orbitals, construction of spin orbitals from orbitals and spin functions

UNIT-III	Approximation Methods in Quantum Mechanics	12 Hours

The need of approximation methods- Variation method – variation theorem with proof, illustration of variation theorem using a trial function [e.g., x (a-x)] for particle in a 1D-box, variation treatment for the ground state of helium atom; Perturbation method – time-independent perturbation method (non-degenerate case only), illustration by application to particle in a ID-box with slanted bottom, perturbation treatment of the ground state of the helium atom. Hartree's Self-Consistent Field method for atoms.

UNIT-IV	**Statistical Mechanics**	**20 Hours**
Microstates and probability. Entropy and its statistical derivation. Gibb's free energy, Gibb's paradox, phase space density, ergodic hypothesis, Liouville's theorem, The microcanonical-, canonical- and grand canonical- ensemble and their connections, Fluctuations, Classical Statistical systems Boltzmann distribution.Fermi-Dirac statistics. Bose-Einstein statistics. The partition function – The partition function for an ideal gas. Relationship of Free energy, pressure and entropy of an ideal gas with partition function.		
UNIT-V	**Contemporary Issues**	**5 Hours**
Seminars, Assignments and webinars		
	Total Lecture Hours	**72 Hours**
Text Books/References		

1. A Text Book of Quantum Mechanics, P.M. Mathews & K. Venkatesan, Tata McGraw Hill, (2010).
2. Quantum Chemistry, Donald, A. McQuarrie, University Science Books, 1983 (first Indian edition,Viva books, 2003).
3. Modern Quantum Mechanics, J. J. Sakurai and Jim Napolitano, Cambridge University Press, third edition, 2020.
4. Problems and solutions in quantum mechanics, K. Tamvakis, Cambridge University Press, 2005.
5. Quantum Physics, Florian Scheck, Springer Science & Business Media, 2007.
6. Introduction to Quantum Mechanics, David J. Griffiths, Cambridge University Press.
7. Quantum Chemistry, I.N. Levine, 6th Edition, Pearson Education Inc.,
8. Molecular Quantum Mechanics, P.W. Atkins and R.S. Friedman, 4th Edition, Oxford University Press, 2005.
9. Quantum Mechanics in Chemistry, M.W. Hanna, 2nd Edition, W.A. Benjamin Inc., 1969.
10. Physical Chemistry – Quantum Mechanics, Horia Metiu, Taylor & Francis, 2006.
11. Introduction to Quantum Mechanics, L. Pauling and E.B. Wilson, McGraw-Hill, 1935 (A good source book for many derivations).
12. Quantum Chemistry, R.K. Prasad, 3rd Edition, New Age International, 2006.
13. Lectures on Chemical Bonding and Quantum Chemistry, C.N. Datta, Prism Books Pvt. Ltd., 1998.
14. Statistical Physics, K. Huang, second edition, Wiley, 1987.
15. An Introduction to Theoretical Chemistry, Jack Simons, Cambridge University Press, 2003.
16. Statistical Mechanics, G S Rush Brook, Oxford University Press.
17. Elements of Statistical Thermodynamics, M C Gupta, New Age International.
18. Statistical Mechanics, Thermodynamics and Kinetics, O K Rice, W H Freeman and Co. Ltd. 1967.

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	L	L	M	M	M
CO2	S	M	S	L	S
CO3	L	M	M	L	S
CO4	S	S	S	M	S
S - Strong		M- Medium		L- Low	

Course Code	**NST.102**	**STRUCTURE AND BONDING IN SOLIDS**	**L**	**T**	**P**	**C**
Core			**4**	**0**	**0**	**4**
Pre-requisite	Should have studied Solid State Physics/Chemistry/Allied chemistry/Applied Chemistry		**Syllabus Version**		**2021-2022**	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Acquire the fundamental concepts of chemical bonding in molecules.
2. Recognize the concepts on bonding in solids and understand their role in determining the properties of the solid.
3. Understand the concepts on crystallography and imperfections in solids.
4. Understand the fundamental principles underlying and connecting the structure, properties and performance of materials.

Course Outcomes

1. Remember the concepts of structure, bonding and imperfections in solids. (K1)
2. Evaluate and apply the concepts of bonding in solids while understanding the properties of nanostructured materials. (K5)
3. Evaluate the concepts of crystal growth for correlating the growth of nanostructured materials.(K5)
4. Apply the concepts of defects while design nanostructured materials for a specific application.(K4)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Chemical Bonding**	**15 Hours**
Types of chemical bonds. The octet rule. Wave Mechanical picture of chemical bonding. Valence bond and Molecular orbital theories, MO diagrams of homonuclear and hetronuclear diatomic molecules. Structure of molecules, VSEPR model. Ionic solids lattice energy, Born-Lande equation		
UNIT-II	**Bonding in Solids**	**18 Hours**
Close packing, voids, radius ratio rule, and Pauling rule-application to actual structures, variations in atomic packing-polymorphism, isomorphism, solid solutions, and derivative structures. Characteristic properties of metals, crystalline and amorphous solids. Theories of bonding in solids. The free electron theory, Band and Zone Theories, the Kronig-Penny model, Classification of solids into insulators, semiconductors, conductors and super conductors. Alloys, ceramics, composite materials and conducting polymers.		
UNIT-III	**Crystallography**	**18 Hours**
Periodicity in crystals, translational periodicity, representation of a lattice, notations of planes in a lattice, relationship between planes. Crystal types, two and three dimensional crystal lattices. Symmetry elements – proper and improper rotation axes, screw axes, glide planes. Symmetry groups- point groups categories of crystal, plane groups, space lattices, space groups, super groups and subgroups		

UNIT-IV	**Imperfections in solids**	**16 Hours**
Types of Imperfections - classification. Point defects - Schottky defects, Frenkel defect, Disordered Crystal. Line defects - Dislocation types, Dislocation theory. Plane defect - Large-angle boundaries, Small – angle boundaries, stacking faults. Colour centers in alkali halides Crystal growth - Velocity, Theories and Mechanism of crystal growth. Twinning - Growth, Deformation and transformation twins. Transformations in Crystals - Equilibrium transformations, Kinetics of transformations Elastic deformation and plastic deformation in crystals.		
UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	TOTAL LECTURE HOURS	**72 Hours**
Text Books/References		

1. Atomic structure and chemical Bond, Manas Chanta **Publisher:** McGraw-Hill Inc.,US (1 December 1974) **ISBN-10:** 0070965110
2. Concise Inorganic chemistry, J.D.Lee **Publisher:** Wiley; 5th edition edition (18 December 1998) **ISBN-10:** 0632052937
3. Inorganic Chemistry, G. Wwfsberg Unit IV **Publisher:** Pearson; 4 edition (31 May 2012) **ISBN-10:** 0273742752
4. Introduction to solids – L.V. Azaroff • **Publisher:** McGraw Hill Education; New edition edition (14 June 2001) **ISBN-10:** 0070992193
5. Introduction to solid state Physics – C. Kittel • **Publisher:** John Wiley & Sons Inc (23 July 1996) • **ISBN-10:** 0471142867
6. Elements of solids state physics, J.P. Srivastava • **Publisher:** Prentice Hall India Learning Private Limited; 4th Revised edition edition (17 December 2014) **ISBN-10:** 8120350669

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	L	M	L	M
CO2	S	M	M	L	S
CO3	S	S	S	M	M
CO4	S	S	S	S	M
S - Strong		M- Medium		L- Low	

Course Code	NST.103	COMPUTATIONAL METHODS & DATA PROCESSING	L	T	P	C
Core			4	0	0	4
Pre-requisite			Syllabus Version		2021-2022	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Distinguish different numerical and statistical tools of analysis
2. Understand the basic idea and need of computational calculations
3. Understand different computational parameters/descriptors.
4. Apply the computational methods for data selection and modeling

Course Outcomes

1. Realize different types of numerical calculations and their importance – K2
2. Awareness about some basic computational calculations – K2
3. Apply different numerical methods for solving problems– K3, K5
4. Understand and apply different softwares for data analysis – K2,K3

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Errors and Statistical Tools in Data Analysis	15 Hours

Significant figures. Errors and classification; accuracy and precision; significant figures and rules; selection of data- T-test; F-test; Q-test; Euler's theorem- exact and inexact differentials; Cartesian-polar-spherical coordinates.

UNIT-II	Mathematical Treatments	20 Hours

Matrices- Direct sum and direct product of square matrices. Block diagonalized matrices. Roots of transcendental equations: Bisection, Regula-Falsi, Iteration and Newton-Raphson methods (SS), Interpolation: Newton's forward, backward & general formula for interpolation. Lagrange formula, Least squares curve fitting: Linear and Nonlinear curve fitting (SS). NI: Trapezoidal and Simpson's methods, Gauss quadrature. LSE: Solution of linear systems, Gauss Elimination, Gauss Jordan method for inverse, LU factorization from Gauss elimination, Matrix transformation (house holder ,Givens method).

UNIT-III	Introduction to Computational Softwares	12 Hours

Different computer languages; need for computational study; basic principles of computational science; different softwares (freeware and commercial)- Excel, Origin, chem. Draw/Chem Sketch, Gaussian 09, Gaussview5, SPSS, VASP, material studio.

UNIT-IV	Introduction to Computational Calculations	20 Hours

Potential energy scanning, saddle points, Stable conformer-local and global minima. Geometry optimization, Molecular orbital, charges, electron density. Frequency calculation and plotting the spectra. Interaction energy. ESP map. Global reactive descriptors. Fukui descriptors. Koopmans's theorem.

UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**

Text Books/References

1. J.M. Mermet, M. Otto, R. Kellner, Analytical Chemistry, Wiley-VCH, 2004.
2. D.A. Skoog, D.M. West, F.J. Holler, S.R. Crouch, Fundamentals of Analytical Chemistry, 8th Edn., Saunders College Pub., 2007.
3. J.G. Dick, Analytical Chemistry, R.E. Krieger Pub.,1978.50
4. J.H. Kennedy, Analytical Chemistry: Principles, Saunders College Pub., 1990.
5. Jenson F, Introduction to Computational Chemistry – John Wiley
6. Cramer C.J., Essentials of Computational Chemistry – John Wiley
7. Young, Computational Chemistry – Wiley Inter Science
8. S.S. Sastry (SS), Introductory Methods of Numerical Analysis, PHI
9. J.B.Scarborough (SB), Numerical Mathematical Analysis, Oxford & IBH
10. Jichun LI, Yi-Tung Chen (CP), Computational Partial Differential Equations Using MATLAB, CRC Press .
11. D.A. Mc Quarrie, Physical Chemistry: A molecular approach, First South Asia Edition 1998
12. An Introduction To Computational Physics, 2nd ed.- Tao Pang(TP), Cambridge University Press, Cambridge(2006)
13. Numerical Recipes in Fortran, The Art of Scientific Computing. W.H.Press etal. (NR),Cambridge
14. R.C. Verma, P.K. Ahluwalia and K.C. Sharma. Computational Physics- An Introduction- New Age International Publishers, New Delhi(1999)
15. Pual l De Vries, A first Course in Computational Physics. John Wiley & Sons, Inc, New York (1994).

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	M	S	M	S
CO2	S	M	S	M	S
CO3	S	M	S	L	S
CO4	S	M	S	L	M
S - Strong		M- Medium		L- Low	

Course Code	NST.104	INTRODUCTION TO NANOMATERIALS	L	T	P	C
Core			4	0	0	4
Pre-requisite	Fundamentals of Physics and Chemistry at Undergraduate level		Syllabus Version		2021-2022	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Recognize the interdisciplinary area of Nanoscience and Technology
2. Realize different nano systems and recognize the advanced tools used for their analysis
3. Understand the reasons behind size dependent physical or chemical properties of nanomaterials
4. Analyze the phase transformation process and understand how to control that process for nanostructure creation
5. Introduce different methods available for the fabrication of nanostructures

Course Outcomes

1. Recognize different nanosystems and the tools for their analysis (K2)
2. Understand the size dependent physical phenomenons observed in nanomaterials (K2)
3. Realize the origin of surface energy, energy minimization and stabilization processes in nanosystems (K2)
4. Understand and apply the kinetics of phase transformation in nanosystems (K2,K3)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Introduction to Nanosystems	11 Hours

Feynmann's vision on nanoscience & technology, bulk vs nanomaterials, natural and synthetic nanomaterials. Quantum confinement in nanostructures- size dependent physical phenomena in semiconductor and metal nanoparticles. Classification of nanostructures, 0D, 1D and 2D nanostructures. Visualization of nanostructures and techniques related.

UNIT-II	Surface Energy	20 Hours

Surface energy and surface stress-origin and estimation of surface energy. Surface Energy minimization:- Sintering Ostwald ripening and agglomeration. Energy minimization by Isotropic and anisotropic surfaces. Surface energy and surface curvature, Surface energy stabilization- electrostatic stabilization, steric stabilization, electro-steric stabilization..

UNIT-III	Size and Shape Dependence of Nanoparticles	20 Hours

Size effect on the morphology of free or supported nanoparticles, Equilibrium shape of macroscopic crystal. Wulff theorem, equilibrium shape of nanometric crystals. Wulff-Kaichew theorem, equilibrium shape of supported nanoparticles. Kinetics of phase transformations, Homogeneous & Heterogeneous nucleation. Controlling nucleation, growth and aggregation in nanoparticle growth, and crystalline Phase Transitions in Nanocrystals.

UNIT-IV	Fabrication of Nanostructures	16 Hours

Bottom-up approaches for nanostructure fabrication:- Self assembly. Top down approaches for nanostructure fabrication- Lithography- Photolithography- Laser lithography and SPM based lithography (AFM & STM) and nanomanipulation.

UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**
Text Books/References		

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao, Imperial College Press, (2006). (for UNIT I & II, 2nd Chapter, Unit III – Chapter 4 (3.2), Unit IV- Chapter 7
2. Nanomaterials and Nanochemistry by C. Brechignac.P. Houdy M. Lahmani Springer-Verlag (2007). (For Unit III-Part I Chapter I)
3. Materials Science and Engineering-An Introduction 7e, William D. Callister, (Wiley, 2007). (Chapter 10. section 1-.2 and 10.3) Unit II.

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	M	M	S	S
CO2	S	S	S	S	S
CO3	S	S	S	M	M
CO4	S	S	S	M	S
S - Strong		M- Medium		L- Low	

Course Code	NST.105	NANO LAB –I	L	T	P	C
Core			0	0	4	4
Pre-requisite	Basic knowledge on different nanomaterials and their interesting properties		Syllabus Version		2021-2022	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Understand and develop practical skill on different synthetic approaches for nanomaterials
2. Apply the physical and chemical phenomenon associated with nanomaterials by choosing suitable synthetic method
3. Develop data collection skill and analyze the data components using analysis software
4. Evaluate the experimental results with the theory associated with nanosystems
5. Hands on experience on using various sophisticated instruments for analysis

Course Outcomes

1. Understand and apply chemical and physical methods for the synthesis of nanomaterials (K2,K3)
2. Understand the advantages and disadvantages choosing a particular method for nanomaterial synthesis (K2)
3. Create awareness on the importance of data collection statistics and analysis of different types of data for proving the concepts studied (K4,K6)
4. Recognize different advanced tools available for data generation and analysis.(K2)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

List of Experiments: 6 Hours/week

1. Synthesis of different sized Ag nanoparticles by aqueous method, Size distribution studies using DLS
2. Synthesis of different sized Au nanoparticles by aqueous method, Size distribution studies using DLS
3. Green Synthesis of Nanoparticles.
4. Sol-gel synthesis of ZnO nanoparticles.
5. Analysis of optical properties of ZnO nanoparticles
6. Geometry optimization and frequency calculation using Gaussian program.
7. Introduction to Origin software for data analysis
8. Structure and physical property elucidation of small molecules using Chem Draw/Chem Sketch.
9. Performing Potential energy scanning and geometry optimization
10. Frequency calculation and interpretations
11. Prediction of electronic transitions and analysis of MOs
12. Calculation of charges
13. Calculation of global reactive parameters through Koopmans's theorem
14. Calculations in solvent phase
15. Prediction of possible conformers and interactions
16. Prediction of correlation coefficient

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	S	S	M	S
CO2	M	S	S	L	M
CO3	S	M	S	M	M
CO4	M	S	S	M	S
S - Strong		M- Medium		L- Low	

Course Code	NST.106	ABILITY ENHANCEMENT COURSE (AEC)	L	T	P	C
Audit Course			1	1	0	2
Pre-requisite	None		Syllabus Version		2021-2022	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Skill identification for students in their respective field of study.
2. Recognize different research methodologies by introducing new research environments
3. Understand the basic concepts of research process
4. Make the student to work in a group by sharing knowledge

Course Outcomes

1. Recognize the skills associated with each student (with academic or industry etc..) (K1)
2. Create research attitude suitable for academia or industry (K6)
3. Understand the process of defining a research problem and the importance of data analysis (K2)
4. Create better communication skill (K6)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	RESEARCH METHODOLOGY	6 Hours
Research- what is research, need of research, types of research, application of research in business. Research process- selection of topic of interest, formulation of a research problem, design a research, construct instrument for data collection, reliability and validity of instrument, sample, data collection, data processing and analysis, displaying results, repeatability, questionnaire designing, research report.		
UNIT-II	**INDUSTRIAL/RESEARCH INSTITUTION VISIT**	**6 Hours**
Understanding basic concepts of research/research process, motivation and objective of research, research problem, familiarize with instruments for data collection.		
UNIT-III	**INTERNSHIP**	**25 Hours**
Experience in new environment, selection of a new topic, formulating a new research problem, data collection, data analysis, discussion of results, presentation of results, research report and publications.		
UNIT-IV	**RESEARCH PRESENTATION**	**5 Hours**
Importance of conferences, seminars, workshops, publications in peer reviewed national / international journals, patents. Power point preparation- Introduction/preample, data display, discussion of results, conclusion, time management, communication.		
	Total Lecture Hours	**42 Hours**

Text Books/References

Research methodology: (Concepts and Cases) Deepak Chawla, Neena Sondhi,
Research methodology (Methods and Techniques) CR Kothari, Gaurav Garg

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	L	M	M	S	S
CO2	M	M	S	S	M
CO3	L	M	S	S	M
CO4	L	M	M	M	S
S - Strong		M- Medium		L- Low	

SECOND SEMESTER

Course Code	NST.201	DESIGN AND SYNTHESIS OF NANOMATERIALS	L	T	P	C
Core Course			4	0	0	4
Pre-requisite	Complete NST.104		Syllabus Version		2021-2022	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Understand different top-down and bottom-up approaches available for nanomaterials synthesis.
2. Apply the knowledge on synthesis to properly design an experiment for nanostructure creation
3. Understand the design criteria for tuning the shape and size of the particles and to correlate with their properties
4. Understand the common lithographic process available for nanostructure creation

Course Outcomes

1. Understand physical, chemical, biological and lithographic techniques available for the preparation of nanoparticles or nanostructures (K2)
2. Create experimental design to control the size, shape and distribution of nanoparticles (K6)
3. Capable of judging the mertis, demerits and selection of a proper synthetic approach for a specific applications.(K5)
4. Apply and analyze the design criteria for the fabrication of nanostructures by lithography (K3,K4)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Physical Methods	20 Hours

Introduction- Spontaneous growth, Evaporation condensation growth, fundamentals of evaporation condensation growth. Vapor –Liquid-Solid (VLS) growth, SWCNT and MWCNT growth mechganisms. Physical Vapour deposition techniques (PVD): Sputtering & Evaporation. Atomic layer deposition, Chemical vapour deposition method (CVD), Molecular beam epitaxy(MBE), & Electrospinning. Laser ablation, Laser pyrolysis, Ball Milling

UNIT-II	Chemical Methods	20 Hours

Nanoparticles through homogeneous & heterogenous nucleation in solution:- Co-precipitation method, Hydrothermal/ Solvothermal synthesis, Template based synthesis, Electrochemical synthesis, Sonochemical routes, Sol- gel, Micelles and microemulsions. Self assembly methods and Langmuir Blodgett (LB) method.

UNIT-III	Biological Methods	11 Hours

Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Viruses as components for the formation of nanostructured materials; Role of plants in nanoparticle synthesis.

UNIT-IV	Lithographic Techniques	16 Hours

Ebeam lithography and SEM based nanolithography. X-ray Lithography, Focused Ion beam lithography, Near field scanning optical microscopy (NSOM). Atomic Force Microscope Lithography - Dip pen lithography. Microcontact printing, nanoimprint.

UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**

Text Books/References

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao , Imperial college Press, (2006). **Publisher:** World Scientific Publishing Company; 2 edition (4 January 2011) **ISBN-13:** 978-9814324557
2. An introduction to Electrospinning and Nanofibers by Seeram Ramakrishna, Kazutoshi Fujihara, Wee Eong Tee, Teck Cheng Lim, Zaveri Ma, World Sci. Pub. Ltd. Singapore, 2005. • **Publisher:** World Scientific Publishing Co Pte Ltd (8 May 2005) **ISBN-13:** 978-9812564542
3. Springer Handbook of Nanotechnology - Bharat Bhusan • **Publisher:** Springer-Verlag (15 May 2006) **ISBN-13:** 978-3540343660
4. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. **Publisher:** CRC Press (15 December 2008) **ISBN-13:** 978-1420047790
5. Introduction to Nanoscale Science & Technology, Di Ventra, Evoy, Heflin, Springer Science, NY, 2004. • **Publisher:** Springer; 1 edition (30 June 2004) **Sold by:** Amazon Asia-Pacific Holdings Private Limited
6. Nanofabrication- Fundamentals and Applications, By Ampere A Tseng, World Scientific, Singapore 2008. • **Publisher:** World Scientific Publishing Co Pte Ltd (18 March 2008) **ISBN-13:** 978-9812705426
7. Nanoparticles and Nanostructured Films- Preparation Characterization and Applications by Janos H. Fendler, WILEY-VCH Verlag GmbH. D-69469 Weinheim (Federal Republic of Germany), 1998. • **Publisher:** Wiley VCH (28 May 1998) **ISBN-13:** 978-3527294435
8. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens • **Publisher:** Wiley-Interscience; 1 edition (30 May 2003) **Sold by:** Amazon Asia-Pacific Holdings Private Limited.

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	S	S	M	M
CO2	S	S	S	M	L
CO3	M	S	S	S	M
CO4	S	S	S	M	M
S - Strong		M- Medium		L- Low	

Course Code	NST.202	CHARACTERIZATION TECHNIQUES OF NANOMATERIALS	L	T	P	C
Core Course			4	0	0	4
Pre-requisite	Basic knowledge in, Physical, Chemical or Biological sciences		Syllabus Version		2021-2022	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. To familiarize and understand the fundamental principles and concepts of characterization of nanostructured materials.
2. To categorize and understand the different techniques used for studying the structural, optical, morphological, thermal, magnetic and electrochemical properties of nanomaterials.
3. To understand the working principle and instrumentation of the characterization instruments.
4. Evaluation and analysis of experimental data obtained from different instrumentation techniques

Course Outcomes

1. Recognize various characterization techniques available for the studying different properties of nanostructured materials. (K1)
2. To apply the knowledge gained to correctly choose the most suitable characterization technique for studying the properties of nanomaterials.(K3)
3. To effectively use the knowledge gained in analyzing the obtained characterization data. (K4,K5)
4. To evaluate the characterization data and nurture the ability to explain the underlying mechanism.(K5)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Spectroscopic Techniques	20 Hours

X-ray Spectroscopy: Powder XRD, Small angle X-ray diffraction, GIXRD, and Single crystalline X-ray diffraction. X-ray fluorescence spectroscopy (XAFS). X-ray Photoelectron Spectroscopy (XPS), Ultraviolet Photoelectron Spectroscopy (UPS). Vibrational Spectroscopy: Raman and IR spectroscopy. Fourier Transfrom techniques- FT-IR and FT Raman. Electronic Spectroscopy: Absorption and Emission Spectroscopy

UNIT-II	Microscopic Techniques	15 Hours

Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM).. Scanning Probe Microscopy: Atomic Force Microscopy, Scanning Tunneling Microscopy (STM), Near field scanning optical microscopy (NSOM). Confocal Laser Scanning Microscopy

UNIT-III	Techniques for Thermal & Mechanical Analysis	15 Hours

Thermal Analysis: TGA, DTG, DTA, DSC - combustion calorimetry- Thermal diffusivity by the laser flash technique- simultaneous techniques including analysis for gaseous products. Mechanical testing- Introduction, tension testing, High strain rate testing of materials, Fracture Toughness testing methods, Hardness testing.

UNIT-IV	**Magnetic & Electrochemical Techniques**	**17 Hours**
Magnetic Vibrating Sample Magnetometer, Mossbauer spectroscopy, ESR, NMR. Magneto-optic Kerr effect. Electrochemical Techniques: Cyclic voltammetry, Electrochemical Impedance, Scanning electrochemical Microscopy, The quartz crystal micro balance.		
UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**

Text Books/References

1. Introduction to Nanoscience and Nanotechnology, by K K Chattopadhyay, PHI Learning Pvt. Ltd. New Delhi 2019, **ISBN-13:** 978-81-203-3608-7.
2. Characterization of Materials Vol 1 &2, by Elton N. Kaufmann, John Wiley and Sons Publication, 2003. New Jersey.
3. Principles of instrumental analysis, Douglas A Skoog, Donald M West, Saunders College, Philadelphia. • **Publisher:** Cengage; 6 edition (1 November 2014) **ISBN-13:** 978-81-315-25579.
4. NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi) **ISBN-13:** 978-0-07-061788-9
5. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander • **Publisher:** Wiley-Blackwell; 2nd Revised edition edition (1 January 1974) **ISBN-13:** 978-0471493693
6. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter • **Publisher:** Springer; 1st ed. 1996. Corr. 6th printing edition (15 April 2005) **ISBN-13:** 978-0306453243
7. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton • **Publisher:** Springer; Softcover reprint of hardcover 1st ed. 2005 edition (12 October 2010) **ISBN-13:** 978-1441938374
8. Springer handbook of Nanotechnology ed. Bharat Bhushan (Springer) • **Publisher:** Springer-Verlag (15 May 2006) **ISBN-13:** 978-3540343660.

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	M	S	S	M	M
CO2	S	S	S	L	M
CO3	L	M	S	L	M
CO4	M	L	S	M	S
S - Strong		M- Medium		L- Low	

Course Code	**NST.203**	**BIO-NANOMATERIALS**	**L**	**T**	**P**	**C**
Core Course			**4**	**0**	**0**	**4**
Pre-requisite	Basic knowledge in physical, chemical and biological sciences		**Syllabus Version**		**2021-2022**	
L= Lecture, T= Tutorial, P- Practical, C= Credits						

Course Objectives

1. To understand the applications of various nanomaterials in biology
2. To analyze the potentials of nanoprobes
3. To evaluate the uses of different nanoprobes
4. To create new functional nanoprobes for advanced applications

Course Outcomes

1. This course is designed to understand (K1) the applications of different nanomaterials in biology.
2. The detailed description of this particular course module will help students to analyze (K2) each nanomaterials' uses at the laboratory level.
3. Towards the end of this course, students could evaluate (K3) which nanoprobes will be ideal for specific applications.
4. Such experience will help to create (K4) novel materials during their Ph.D. career.

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Nanomaterials for Bio-labeling and Bio-imaging**	**20 Hours**
Different methods for bio-labeling, bio-conjugate chemistry, and variety of nanoprobes (carbon nanomaterials, semiconductor quantum dots, metal nanoclusters, polymer nanoparticles, up conversion nanoparticles, plasmonic nanoparticles), etc. Raman imaging, fluorescence imaging, magnetic resonance imaging, positron emission tomography, photoacoustic imaging, ultrasound imaging, X-ray computed tomography, etc.		
UNIT-II	**Nanomaterials for Delivery and Therapeutics**	**20 Hours**
Different techniques to deliver drugs, gene, mRNA, etc. Photothermal therapy, photodynamic therapy, chemotherapeutics, etc.		
UNIT-III	**Nanomaterials for Tissue Engineering**	**14 Hours**
Introduction, Artificial implants, scaffolds used for tissue engineering based on nanomaterials – bones, skin and neurons.		
UNIT-IV	**Nanomaterials for bioelectronics**	**13 Hours**
Nanoparticle-biomaterial hybrid systems for bioelectronic devices, nanoparticle-enzyme hybrids; bio-recognition. Biomaterial based metallic nanowires, networks and circuitry. DNA as functional template for nanocircuitry; Protein based nanocircuitry.		
UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**

Text Books/References

1. Nanomaterials and Their Applications in Bio-imaging (Plant nanobiotics) by Prasad, R. **Publisher**: Springer, **2019**, ISBN: 9783030164386.
2. Carbon Nanomaterials for Bio-imaging, Bio-analysis, and Therapy in Nanocarbon Chemistry and Interfaces by Hui, Y. Y.; Chang, H.-C.; Dong, H.; Zhang, X. **Publisher**: John Wiley & Sons, **2018**, ISBN: 978-1119373452.
3. Nanotechnology for Biomedical Imaging and Diagnostics: From Nanoparticle Design to Clinical Applications by Berezin, M. Y. **Publisher**: John Wiley & Sons, **2014**, ISBN: 9781118121184.
4. Nanofabrication towards biomedical application: Techniques, tools, Application and impact by Challa S., Kumar, S. R.; Carola. **Publisher**: J. H. John Wiley & Sons, **2005**; ISBN: 9783527311156.
5. Tissue Engineering, Palsson, B. O.; Bhatia, S. N. Publisher: Prentice Hall, 2003; ISBN:
6. Lanza, R.; Langer, R.; Joseph, P. Principles of Tissue Engineering. **Publisher**: Academic Press. **2013**; ISBN-10: 0130416967.
7. Nanobioelectronics for Electronics, Biology, and Medicine by Offenhäusser, Andreas, Rinaldi, Ross, **Publisher**: Springer, **2009**; ISBN: 9781441918574.

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	S	M	M	M
CO2	S	S	M	M	M
CO3	S	S	S	M	M
CO4	S	S	M	M	M
S - Strong		M- Medium		L- Low	

Course Code	NST.204	PROPERTIES AND APPLICATIONS OF NANOMATERIALS	L	T	P	C
Core Course			4	0	0	4
Pre-requisite	Complete the course introduction to nanomaterials. Basic knowledge in physical, chemical and biological sciences		Syllabus Version		2021-2022	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Understand the fundamental principles and concepts related to the electronic and electrical properties of nanomaterials
2. Understand the fundamental principles and concepts related to the optical and photonic properties of nanomaterials
3. Understand the fundamental principles and concepts related to the magnetic properties of nanomaterials
4. Understand the fundamental principles and concepts related to the mechanical and thermal properties of nanomaterials

Course Outcomes

1. Understand the size dependent material properties of nanostructured materials (K2)
2. Apply the size and shape dependence of materials properties for tuning the material for various applications (K3)
3. Will be able to evaluate and correlate the structure-property optimization using the data collected from different analysis. (K5,K6)
4. Review the advantages of using nanostructured materials for various applications and the challenges that will face while using nanomaterials (K5)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Electronic and Electrical properties	16 Hours

Introduction- Nano electronics - Fundamental types of electronic nanomaterials. Microelectronics - Band structure- conductor and semiconductor. Electrical conductivity in nanotubes and nanorods and nanocomposites. Photoconductivity of nanorods. Electronic transport in nanostrutures, Quantum waveguides, single electron transfer devices (SETs), Electron spin transistor – resonant tunnel devices - quantum interference transistors (QUITs).

UNIT-II	Optical and Photonic Properties	16 Hours

Interaction of light with matter. The nano perspective. The surface plasmon – SPR and scattering – color generation from nanoparticles and nanostructures- applications of nanoplasmonics. Quantum dots – Optical properties related to quantum confinement.Special luminescent nanocomposites-electroluminescence- photochromic and electrochromic nanomaterials.

Confinement and propogation of photons. Internal reflection and evanescent waves, Near Field Optics- near field scanning optical microscopy (NSOM or SNOM). Nanophotonic and Plasmonic Applications: nanolasers; nanoantennas; photonic crystals; optical communication; sensing; negative refraction; metamaterials; cloaking; nanostructures for large-area opto-electronics

UNIT-III	**Magnetic Properties:**	**16 Hours**
Introduction – magnetic phenomena and their classical interpretation- the nanoperspective. Introduction to nanomagnetism- characteristics of nanomagnetic materials- Magnetization and nanostructures. Superparamagnetic particles- susceptibility and related phenomena in superparamagnets- Magnetism in reduced dimensional systems- Two, one and zero dimensional systems. Physical properties of magnetic nanostructures - exchange coupled magnetic nanomaterials- spin –polarized tunneling- magnetoresistivity, GMR. Spintronics, Magneto electrical effects, ferrofluids, molecular nanomagnets, data storage applications of magnetic nanoparticles, Spintronic devices and applications.		
UNIT-IV	**Mechanical & Thermal properties**	**19 Hours**
Nanomechanics- Introduction- three atom chain- lattice mechanics- linear elasticity relations – molecular dynamics. Structure and mechanical properties of carbon nanotubes- nanomechanical measurement techniques- AFM – Nanoindentation. Nanothermodynamics:- Thermodynamics the nano perspective – Background- application of classical thermodynamics to nanomaterials- small system thermodynamics. Modern nanothermodynamics- Nonextensivity and nonintensivity – nanothermodynamics of a single molecule – modeling nanomaterials.		
UNIT-V	**Contemporary Issues**	**5 Hrs**.
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**
Text Books/References		

1. Nanomaterials – An Introduction to synthesis, Properties and Applications, by Dieter Vollath, Wiley – VCH Verlag GmbH & Co. Germany, 2008.
2. Properties of nanomaterials by Charles P. Poole
3. The Physics & Chemistry of Nanosolids by Frank J. Owens and Charles P. Poole Jr. , John Wiley & Sons, Inc. New Jersey 2008.
4. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009.
5. Introduction to Nanoelectronics, by V. Mitin, V. Kochelap, M. Stroscio, **Cambridge University Press (2008).**
6. Nanoelectronics and Photonics: From Atoms to Materials, Devices,and Architectures by Anatoli Korkin l Federico Rosei, **2008 Springer Science, Business Media, LLC.**
7. Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Devices, by Rainer Waser, **Wiley-VCH (2003).**
8. Nanoelectronics and Nanosystems, by Karl Goser, Peter Glosekotter, Jan Dienstuhl, **Springer (2004**).
9. Nanotechnology & Nanoelectronics, Materials, devices, measurement techniques, by W. R. Fahrner(Editor), **Springer, 2005**
10. Principles of Nanophotonics, by Motoichi Ohtsu, Kiyoshi Kobayashi, Tadashi Kawazoe,Takashi Yatsui,Makoto Naruse**, CRC press 2008 by Taylor & Francis Group**
11. Semiconductor Quantum Dots, L. Banyai and S.W.Koch, **World Scientific (1993).**
12. NanoBiophotoics, H. Masuhara, S. Kawata and F. Tokunga, **Elsevier Science, (2007).**
13. Fundamentals of Photonics, B. E. A. Saleh and A. C. Teich, John Wiley and Sons, NewYork, (1993).
14. Introduction to Biophotonics, P. N. Prasad **John Wiley and Sons, (2003).**
15. Molecular Nanomagnets, Dante Gatteschi, Roberta Sessoli, Jacques Villain, Oxford **University Press 2006, USA.**

16. Concepts in Spin Electronics, Sadamichi Maekawa, **Oxford University Press (2006).**
17. Nanomagnetism and Spintronics: Fabrication, Materials, Characterization and Applications
18. Farzad Nasirpouri , Alain Nogaret **Publisher:** World Scientific Publishing Company; edition (December 21, 2010) **ISBN-10:** 9814273058
19. Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, Edward L. **Wolf Wiley-VCH (2006).**
20. Biomineralization: Principles and Concepts in Bioinorganic Materials Chemistry. Mann, S., **2001. New York, Oxford University Press.**
21. Nanoscale Technology in Biological Systems, Edited by Ralph S. Greco, Fritz B. Prinz, R. Lane Smith**, CRC Press, USA, 2005.**
22. Nanoparticle Technology for Drug delivery, Ram B.Gupta, Uday, B.Compella, **2006 Taylor & Francis Group, LLC, NY.**
23. Nanoparticulates as Drug Carriers, Vladimir Ptorchilin, **Imperial College Press, London, 2006.**
24. Hybrid Nanocomposites for Nanotechnology, Electronic, Magnetic, Optical and Biomedical Applications,by Lhadi Merhari, **Springer USA 2009.**

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	S	S	S	M
CO2	S	M	S	S	M
CO3	S	M	S	M	L
CO4	M	L	S	S	M
S - Strong		M- Medium		L- Low	

Course Code	**NST.205**	**NANO LAB –II**	**L**	**T**	**P**	**C**
Core			**0**	**0**	**4**	**4**
Pre-requisite	Basic knowledge on different nanomaterials and their interesting properties		**Syllabus Version**		**2021-2022**	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Understand and develop practical skill on different synthetic approaches for nanomaterials
2. Apply the physical and chemical phenomenon associated with nanomaterials by choosing suitable synthetic method
3. Develop data collection skill and analyze the data components using analysis software
4. Evaluate the experimental results with the theory associated with nanosystems
5. Hands on experience on using various sophisticated instruments for analysis

Course Outcomes

1. Understand and apply the concept of quantum confinement for tuning the optical properties of semiconducting QDs. (K2, K3)
2. Evaluate and interpretation the data obtained experimentally (K5)
3. Understand the documentation and presentation of experimental data (K2)
4. Recognize different computational calculations and their interpretation in nanosystems (K1)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

List of Experiments: 6 Hours/week

1. Chemical synthesis of CdSe Quantum dots with different sizes.
2. Band gap estimation of CdSe quantum dots by using optical spectroscopy
3. Exciton and plasmon interaction studies of Au-CdSe system by using optical spectroscopy
4. Operation of Electrochemical Workstation
5. Deposition of Polyaniline on ITO/FTO using Electrochemical Workstation.
6. Structural elucidation of Electrodeposited polyaniline using FTIR
7. Chemical Synthesis of Magnetic nanoparticles and size determination.
8. Electrochemical synthesis of TiO2 Nanostructures. Optical Studies by using UV-VIS spectrophotometer. Electronic structure analysis by using Cyclic Voltammetry.
9. Electrochemical Synthesis of ZnO nanorods - Optical Studies by using UV-VIS spectrophotometer. Electronic structure analysis by using Cyclic Voltammetry.
10. Thin film deposition of TiO_2 and ZnO by Electrochemcial method – Study the optical and

electronic properties.

11. Compare the results of 1D structure with 2D thin films of both TiO_2 and ZnO.
12. Thin film preparation using spin coating method and thickness measurement using Profilometer.
13. Hall measurements of electrodeposited TiO2 thin films
14. Calculation of fukui parameters
15. Calculation of global reactive parameters through orbital energy method
16. Calculation of binding/stabilization energy
17. Prediction of donor-acceptor interactions
18. Study of metal complexes
19. Calculation with periodic boundary conditions
20. ONIOM calculation
21. NBO analysis
22. Toxicity prediction
23. ADME calculation
24. Validation of Lipinski rule of 5
25. 2D-QSAR

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	S	M	S	M
CO2	S	S	S	M	S
CO3	S	M	S	S	M
CO4	L	S	M	M	S
S - Strong		M- Medium		L- Low	

Course Code	**NST.206**	**PROFESSIONAL COMPETENCY COURSE (PCC)**	**L**	**T**	**P**	**C**
Audit Course			**1**	**1**	**0**	**2**
Pre-requisite	None		**Syllabus Version**		**2021-2022**	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Inculcate scientific writing and communication skill
2. Understand the basic ethical issues confronted by the scientist
3. Recognize the skill areas the student would like to develop
4. Create awareness on the fundamentals of technology transfer

Course Outcomes

1. Understand the scientific paper or thesis writing skill (K2)
2. Realize the ethical issues associated with scientific research and capable to analyze and address unethical situations (K2,K4)
3. Able to evaluate their own values and interests as they relate to their professional careers. (K5)
4. Understand the fundamentals of technology transfer and issues related (K2)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Scientific Writing and Communication Skill**	**12 Hours**

Writing and communication skill is very much essential to express scientific ideas or results clearly to validate their significance. For the successful publication of a research work, development of scientific writing skill is essential. Writing Research report, research proposals. Every aspect of writing scientific grants from funding agencies. Introduction to every aspect of grant writing, including selecting funding mechanisms, writing individual grant sections and understanding administrative policies. Strategies for effective scientific writing-core elements of each sections- Principles of writing research manuscript by composing and editing the sections- Familiarization with reference manager- how to peer review an article from the perspective of a researcher- reviewer- journal editor – complete and submit a research manuscript (based on an abstract given). Patent filing.

UNIT-II	**Integrity in Scientific Research**	**10 Hours**

Familiarize the graduate students with the basic ethical issues confronted by the scientist. To gain insight into how one can responsibly conduct research throughout their career - To know how to properly address unethical situations- To realize that new ethical issues/ concerns will arise and that the best way to tackle these will be to discuss ethical situations with colleagues, seek guidance from proper channels, and routinely participate in conduct of research training courses/ seminars. Importance of team work, group discussion and collaborative research (MOU etc.), Know about plagiarism.

UNIT-III	**Individual Development Plan**	**10 Hours**
Individual development plan is intended for the graduate students before they go on to job market. Give opportunity to the participants to evaluate their own values and interests as they relate to their professional careers. Introduce the students to three or four different career tracks such as industry (profit or non profit), government sector, academic, scientific institution, etc.. ask the student to identify the skill areas they would like to develop.		
UNIT-IV	**Fundamentals of Technology Commercialization**	**10 Hours**
Innovative transformation of scientific and technical knowledge into commercial products and services. Importance of cross-disciplinary teams of students to asses real technologies for commercial applications with a specific focus on developing an understanding of the commercialization process, and skills in licensing and new venture development. Introduce concepts that improve and accelerate the commercialization process. From decisions made by scientists at the research bench, through the development, patenting, and licensing of new technologies, to the formation of entrepreneurial enterprises and monetization of assets. Data sharing with stake holders.		
	Total Lecture Hours	**42 Hours**

Text Books/References

1. The Craft of Scientific Writing, Michael Alley, 4th Ed. Springer, New York, USA (2018)
2. A Guide to the Scientific Career: Virtues, Communication, Research and Academic Writing Edited by Mohammedali M Shoja et.al, Wiley Black well (2019).
3. Handbook of Science Communication by Anthony Wilson, Jane Gregory, Steve Miller, Shirley Earl, IOP Publishing (1999).

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	L	L	M	L	S
CO2	L	L	M	S	S
CO3	L	L	M	S	S
CO4	L	M	M	S	S
S - Strong		M- Medium		L- Low	

THIRD SEMESTER

Course Code	**NST.301**	**ADVANCED NANOMATERIALS**	**L**	**T**	**P**	**C**
Core Course			**4**	**0**	**0**	**4**
Pre-requisite	Basic Knowledge in Nanoscience and Nanomaterials		**Syllabus Version**		**2021-2022**	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. To understand the importance of advanced nanostructured materials and their properties.
2. To understand the concepts of functionalization of carbon nanotubes and analyze the change in the physical and chemical properties.
3. To understand the properties of micro and mesoporous materials and their applications.
4. To understand the properties of ultrahard smart materials and nanocomposites.

Course Outcomes

1. To remember the various type of advanced nanostructured materials that could be utilized for various applications.(K1)
2. To apply the concepts of functionalization while designing CNT composites for a specific application. (K3)
3. To apply the knowledge gained while designing novel nanocomposites.(K3)
4. To nurture the ability of critical thinking towards the design and development nanostructured materials for a specific application.(K6)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Carbon Nanostructures**	**20 Hours**

Introduction:- Diamond – Graphite- Fullerenes, CNTs and Graphene. Synthesis: CVD, Laser and Electrochemical and other methods. Functionalization and reactivity of CNTs, Covalent Functionalization -Oxidative Purification, Defect Functionalization –Sidewall Functionlaization, Noncovalent Exohedral Functionalization, Endohedral Functionalization.

UNIT-II	**Special Nanomaterials**	**16 Hours**

Micro & Mesoporous Materials - Ordered mesoporous structures, Random mesoporous structures, and crystalline microporous materials: zeolites. Core – Shell Structures - Metal-oxide structures, Metal-polymer structures, Oxide-polymer structures. Organic-Inorganic Hybrids- Class I hybrids, Class I1 hybrids, Intercalation Compounds.

UNIT-III	**Ultra Hard Smart Materials**	**15 Hours**

Introduction- synthesis properties and applications of ultra nanocrystalline diamond-growth,electronic properties and application of nanodimond. Dimond like materials- CNTS and Nitrides, C_3N_4-Boron nitride etc.

UNIT-IV	**Nanocomposites**	**16 Hours**

Introduction to Nanocomposites – Layered Silicates-Polyamide-clay nanocomposites. Epoxy nanocomposites based on layered silicates and other nanostructured fillers. Biodegradable polymer silicate nanocomposites. Metal Polymer Nanocomposites-synthesis- Ex-situ and in-situ approaches-Optically anisotropic metal –polymer nanocomposites. Conducting nanocomposite systems- Introduction, classification and host guest materials for nanocomposite systems.

UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**
Text Books/References		

1. Carbon Materials & Nanotechnology, By Anke Krueger, Wiley VCH Verlag **GmbH & Co. KGaA, 2010, Weinhein.**
2. Dimond Nanotechnology- Synthesis and Applications, by James Sung, Pan **Stanford Publishing (July 31, 2009)**
3. Nanostructures and Nanomaterials - Synthesis, Properties and Applications - Cao, Guozhong, **Imperial college press, 2004.**
4. Polymer nanocomposites, Edited by Yiu-Wing Mai and Zhong-Zhen Yu, **CRC Press, Woodhead Publishing Limited, 2006.**
5. The New Frontiers of Organic and Composite Nanotechnology, Victor Erokhin, Manoj Kumar **Ram and Ozlem Yavuz, 2008 Elsevier Ltd.**
6. Metal – Polymer nanocomposites by Luigi Nicolais and Gianfranco Carotenuto, **John Wiley & Sons, Inc. 2005.**
7. Nanoscale materials -Liz Marzan and Kamat **Publisher:** Wiley; 2 edition (2009)
8. Synthesis functionalization and surface treatment of nanoparticles - Marie Isabelle Baraton
9. Physical properties of Carbon Nanotube-R Satio **Publisher:** Am. Sci. Publishers (2002)
10. Applied Physics Of Carbon Nanotubes : Fundamentals Of Theory, Optics And Transport devices , S. Subramony & S.V. Rotkins **Publisher:** Springer; 2005 edition.
11. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell **Publisher:** CRC Press; edition (2006)
12. Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing **Publisher:** Royal Society of Chemistry.
13. Nanosilicon by Vijay Kumar, Elsevier Ltd. UK ,2007. **Publisher:** Elsevier Science (2014)

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	L	M	M	M	L
CO2	M	S	S	M	L
CO3	M	S	S	M	L
CO4	L	M	S	S	M
S - Strong		M- Medium		L- Low	

Course Code	NST.302	COMPUTATIONAL NANOTECHNOLOGY	L	T	P	C
Core Course			4	0	0	4
Pre-requisite	Basic knowledge in computational process and data analysis		Syllabus Version		2021-2022	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Introduction to different computational tools
2. Understand the need and importance of computational studies to support scientific results
3. Create skills to write z-matrix
4. Understand different simulations and its applications of small systems

Course Outcomes

1. Recognize different computational tools. (K1)
2. Apply the computational tools to model or analyze scientific concepts or results (K3,K4)
3. Evaluate different computed results through various methods. (K5)
4. Apply the computational knowledge to explain the interesting properties of nanosystems (K3)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	Introduction to Computational Methods	15 Hours

Basis sets- different types: primitive to complex basis sets. Polarized, diffused and plane wave basis sets. Basis set truncation error. Electron correlation. Correlation energy. Basis set limit. Slater type orbitals and Gaussian type orbitals; z-matrix- basic idea and construction. Z-matrix of small molecules like H_2O, HCHO, CH_3OH and H_2O_2.

UNIT-II	Classification of Computational Methods	20 Hours

General classification- Classical and quantum mechanical. Molecular mechanics. Semi-Empirical method. Ab initio method. Density functional theory method. Molecular dynamics. ONIOM method. Simulations.

UNIT-III	Computational Chemistry	20 Hours

Combinatorial chemistry. QSAR/QSPR study. Analysis of global reactive descriptors, fukui indices; thermochemical calculations- feasibility, catalysis and equillibrium. TDDFT and calculation of band gap. Analysis of MOs; NBO analysis; Reaction mechanism- TS and IRC pathway. Stability and adsorption studies.

UNIT-IV	Computational Nanotechnology	12 Hours

Quantum confinement; change in properties with size. Applications of computational studies in nanotechnology. Simulations- different types-Monte Carlo Methods (Detailed treatment). Nano-computing and modelling. Computing transport in materials. Nanodesign Nano-CAD.

UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**

Text Books/References

1. D. Frenkel and B. Smith, ―Understanding molecular simulation from algorithm to applications‖, Kluwar Academic Press, 1999.
2. K. Ohno, K. Esfarjani and Y. Kawazoe, ―Introduction to Computational Materials Science from ab initio to Monte Carlo Methods‖, Springer-Verlag, 1999.
3. Jenson F, Introduction to Computational Chemistry – John Wiley
4. Cramer C.J., Essentials of Computational Chemistry – John Wiley
5. Young, Computational Chemistry – Wiley Inter Science
6. Andrews R. Leach, Molecular Modeling – Pearson
7. Ramachandran K.I et al computational Chemistry and Molecular Modeling Springer.
8. Schlick. T., Molecular Modeling and Simulations, Springer.

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	L	M	M	M	M
CO2	S	S	S	S	S
CO3	M	L	S	M	M
CO4	S	S	S	S	S
S - Strong		M- Medium		L- Low	

<table>
<tr><td>Course Code</td><td>NST.303</td><td rowspan="2">SOCIETAL & ENVIRONMENTALIMPACT OF NANOTECHNOLOGY</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Core Course</td><td>2</td><td>0</td><td>0</td><td>2</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge in Nanoscience</td><td colspan="2">Syllabus Version</td><td colspan="2">2021-2022</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
</table>

Course Objectives

1. Awareness on the factors influencing public perception on nanoscience and related area
2. Understand Intellectual Property Rights (IPR) and policies and laws associated with it
3. Recognize environmental regulations pertinent to nanotechnology
4. Aware of the issues and challenges associated with the toxicity and risk assessment of nanoparticles

Course Outcomes

1. Understand the ethics associated with scientific research and analyze the factors influencing public perception on nanoscience. (K2, K4)
2. Understand the importance of IPR and create interest to patent novel research work (K2,K6)
3. Recognize the importance of sustainable nanotechnology (K2)
4. Understand the methods to evaluate the toxicology and risk assessment associated with nanomaterials (K2,K5)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Ethics and Society**	**10 Hours**

Introduction to societal issues- societal implications – the background- breadth of societal implications – meet the experts- the nano perspective. Ethical implications – Ethics in the context of research and applied science- principle of respect for communities- principle of the common good- principle of social justice- you as moral agent. Public perception: Factors influencing public perception- nano and public opinion polls- A call for two way communications.

UNIT-II	**Intellectual Property Rights (IPR)**	**10 Hours**

Types of IP: Patents, Trademarks, Copyright & Related Rights, Industrial Design, International framework for the protection of IP. International Databases; Country wise patent searches (USPTO, EPO, India etc.). Indian and International Patents; Patent application forms and guidelines, fee structure, time frames, financial assistance for patenting. IPR policy of Government of India, Indian & International Patent laws,

UNIT-III	**Health and Environmental risk**	**10 Hours**

Developing Environmental Regulations Pertinent to Nanotechnology, Analyses of Nanoparticles in the Environment, , Ecological hazards of nanomaterials. Assessing nanotechnology health risk, treatment of nanoparticles in waste water, nanoparticles in pollutioncontrol, Development of sustainable nanotechnology.

UNIT-IV	**Toxicology and Safe Handling**	**7 Hours**
Toxicology and risk assessment, determination of potential toxicity, nanoparticles in work place, biodistribution and interaction of nanoparticles, nanoparticle dose in humans- issues and challenges.		
UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**42 Hours**
Text Books/References		

1. Nanotechnology: Ethics and Society, Deb Bennett-Woods, CRC Press, Tylor & Francis Group New York,2008.
2. Nanotechnology , Legal Aspects, by Patrick M. Boucher, CRC Press, Tylor & Francis Group New York,2008.
3. Nanotechnology and the Environment, Kathleen Sellers, Christopher Mackay, Lynn L. Bergeson,Stephen R. Clough, Marilyn Hoyt, Julie Chen, Kim Henry, Jane Hamblen, CRC Press, Tylor & Francis Group New York,2009.
4. Nanotechnology: Health and Environmental Risks, Jo Anne Shatkin, CRC Press, Tylor & Francis Group New York, 2008.
5. Nanotoxicology, Characterization, Dosing and Health Effects, Nancy A. Monteiro-Riviere, C. Lang Tran, Informa Healthcare USA, Inc. 2007.
6. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009.
7. P. Narayanan, Intellectual Property Laws, Eastern Law House.2001
8. Meenu Paul, Intellectual Property Laws, Allahabad Law Agency.2009
9. Intellectual Property Law containing Acts and Rules, Universal Law Publication Company.

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	L	L	M	L	M
CO2	L	L	M	S	S
CO3	L	L	S	S	S
CO4	M	M	S	S	S
S - Strong		M- Medium		L- Low	

<table>
<tr><td>Course Code</td><td>NST.304-A</td><td rowspan="2">NANOMATERIALS FOR ENERGY CONVERSION AND STORAGE</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Elective</td><td>4</td><td>0</td><td>0</td><td>4</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge in Nanoscience</td><td colspan="2">Syllabus Version</td><td colspan="2">2021-2022</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
</table>

Course Objectives

1. Conscious of energy crisis, its reason, current status and possible solutions
2. Recognize renewable and non-renewable energy resources and their contribution towards global energy production
3. Importance of re-newable energy resources and tapping such energies
4. Role of Nanoscience or nanotechnology in producing novel materials and designs for efficient production of energy using renewable resources

Course Outcomes

1. Analyze the reasons for energy crisis and understand the importance of sustainable energy development (K4,K2)
2. Understand Hydrogen economy and advantages and challenges of Hydrogen fuel and its production (K2)
3. Understand the possibilities of solar energy production using nanostructured materials and create awareness on using solar panels for house hold and other energy usages. (K2,K6)
4. Analyze the importance of novel energy storage devices with improved performance using nanoscience (K4)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Primary perspective in energy conversion**	**14 Hours**

Current energy scenario; Energy and climate:- Green house effect, conventional energy sources Vs non-conventional energy sources. Outline of alternative energy schemes – solar, wind, biomass, hydro, and nuclear. Clean low cost, sustainable energy development, prospects of renewable energy.

UNIT-II	**Electrochemical Energy conversion**	**16 Hours**

Electrochemical Cell, Polarization losses in electrochemical cells, Thermodynamics of electrochemical energy conversion, Efficiency of electrochemical energy conversion, and Electrode kinetics. Fuel Cells- relevance and importance, classification of fuel cells, Proton exchange membrane fuel cells (PEMFC); Direct methanol fuel cells (DMFC); Solid-oxide fuel cells (SOFC), Issues and challenges of functional nanostructured materials for electrochemical energy conversion systems.

UNIT-III	**Photovoltaic Solar Energy Conversion**	**20 Hours**

Properties of sunlight: Solar radiation at earth's surface- Air Mass. Principles of photovoltaic energy conversion (PV), Types of photovoltaic Cells. Si solar cells- Structure, and working.

Fundamentals of nanostructured solar cells, nanostructures in conventional thin film solar cells. Dye sensitized solar cells(DSSC), Quantum dot sensitized solar cells (QDSSC), Organic solar cell, Organic-Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Nanostructured ETA solar cells, Current status and future direction.		
UNIT-IV	**Energy Storage**	**17 Hours**
Primary and Secondary Batteries-Lithium ion Batteries, nanostructured cathode and anode materials. Capacitors, Electrochemical supercapacitors, electrical double layer model, Principles and materials design, Nanostructured Carbon based materials, nano-Oxides, and conducting polymers based materials, Issues and Challenges.		
UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**
Text Books/References		

1. Nanostructured Materials for Solar Energy Conversion, By Tetsuo Soga, 2006 Elsevier B.V. All rights reserved.
2. PVCDROM, http://pveducation.org/pvcdrom
3. Aldo V. da Rosa, *Fundamentals of Renewable Energy Processes, 2nd Edition* (Elsevier Academic Press, 2009).
4. Fuel cells- principals and Applications, by B.Viswanathan, M.Aulice Scibioh, Universities Press, India, 2006.
5. Green Chemistry and Chemical Engineering, Pronton Exchange Membrane Fuel Cells Contamination and Mitigation Strategies, By hui Li, Shanna Knights, Zheng Shi, John W. Van Zee, Jin Jun Zhang, Taylor and Francis Group, 2010, USA.
6. Martin A. Green, *Solar Cells: Operating Principles, Technology, and System Approaches* (Prentice-Hall, 1998)
7. Jenny Nelson, *The Physics of Solar Cells* (Imperial College Press, 2003)
8. D. Linden Ed., Handbook of Batteries, 2nd edition, McGraw-Hill, New York (1995)
9. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kulwer Acdemic Publishers, Dordrecht, Netherlands (2004).
10. J. Larmine and A. Dicks, Fuel Cell System Explained, John Wiley, New York (2000).

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	L	M	M	S	S
CO2	L	M	S	S	S
CO3	M	S	S	S	S
CO4	M	M	S	S	S
S - Strong		M- Medium		L- Low	

Course Code	**NST.304-B**	**ADVANCED SPECTROSCOPY AND MICROSCOPY**	**L**	**T**	**P**	**C**
Elective			**4**	**0**	**0**	**4**
Pre-requisite			**Syllabus Version**		**2021-2022**	
						L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. To understand the characteristics of individual nanomaterials
2. To analyze the optoelectronic properties of nanomaterials
3. To evaluate the uses of different nanomaterials
4. To create novel nanomaterials for contemporary applications

Course Outcomes

1. This course is designed for those students who require a detailed understanding (K1) of individual nanomaterials.
2. The detailed spectroscopy and microscopy will help students to analyze (K2) each nanomaterial deeply.
3. Towards the end of this course, students will be able to characterize and evaluate (K3) the nanomaterials' properties by looking into the spectroscopic and microscopic data.
4. Such experience will be beneficial to create (K4) an excellent research skill during their Ph.D. program.

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Spectroscopy-I**	**20 Hours**

Principles of UV/Vis absorption spectroscopy, Fluorescence spectroscopy, Photoelectron spectroscopy (X-ray and Ultraviolet), X-ray Fluorescence, Augur electron spectroscopy, Electron energy loss spectroscopy, Infrared spectroscopy (IR), Attenuated total internal reflection IR spectroscopy, Surface enhanced IR spectroscopy, Raman spectroscopy, Surface enhanced Raman spectroscopy, Confocal Raman spectroscopy, Tip-enhanced Raman spectroscopy.

UNIT-II	**Spectroscopy-II**	**20 Hours**

Principles of Nuclear magnetic resonance spectroscopy (NMR; ^{1}H, ^{13}C, ^{19}F, and ^{31}P), Two-dimensional NMR spectroscopy (ROESY, COSY, NOESY), Electron paramagnetic resonance spectroscopy (EPR), Mass spectroscopy (matrix assisted laser desorption ionization, laser desorption ionization, and electrospray ionization mass spectrometry), and applications of individual spectroscopy in nanomaterials.

UNIT-III	**Microscopy -I**	**16 Hours**

Principles of Transmission electron microscopy (TEM), TEM-tomography, Scanning electron microscopy (SEM), Atomic force microscopy (AFM), and Scanning tunneling microscopy (STM).

UNIT-IV	**Microscopy -II**	**11 Hours**

Principles of Fluorescence microcopy (Epifluorescence, Confocal fluorescence microscopy, Total internal reflection microcopy, and Stimulated emission depletion microscopy), Raman microscopy, and applications of individual microscopy in nanomaterials.

UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**

Text Books/References

. Handbook of Analytical Techniques by Helmut Gunzler and Alex Williams, **Publisher**: Wiley-VCH, **2001**; ISBN: 9783527301652.

2. Fundamentals of molecular spectroscopy by C. Banwell and E. Mccash, **Publisher**: Mc Graw Hill, **1994**; ISBN: 9781259062599.

3. Surface Analysis Methods in Materials Science by J. O'Connor, B. Sexton, R. Smart, **Publisher**: Springer, **2003**; ISBN: 9783540413301.

4. Modern Techniques of Surface Science by D.P. Woodruff, **Publisher**: Cambridge University Press, **2016**; ISBN: 9781139149716.

5. Mass spectrometry- Principles and applications by Edmond de Hoffmann and Vincent Stroobant, **Publisher**: John Wiley & Sons, **2007**; ISBN: 9780470033104.

6. NMR Spectroscopy: Basic Principles, Concepts and Applications in Chemistry by Harald Gunther, **Publisher**: John Wiley & Sons, **2013**; ISBN: 9783527330003.

7. Modern Spectroscopy by J. Mixhael Hollas, **Publisher**: John Wiley & Sons, **2004**, ISBN: 9780470844168.

8. Fundamentals of Light Microscopy and Electronic Imaging by Douglas B. Murphy, **Publisher**: Wiley-Blackwell, **2012**; ISBN: 9780471692140.

9. Introduction to Fluorescence Microscopy by Ploem J. S. Tanke H. J. **Publisher**: Royal Microscopical Society Microscopy Handbooks No. 10, **2004**; ISBN: 0198564082.

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	S	S	S	M
CO2	S	S	M	M	M
CO3	S	S	S	M	M
CO4	S	S	M	M	M
S - Strong		M- Medium		L- Low	

Course Code	**NST.304-C**	**NANOMATERIALS FOR PHOTOCATALYSIS AND SOLAR FUEL GENERATION**	**L**	**T**	**P**	**C**
Elective			**4**	**0**	**0**	**4**
Pre-requisite	Basic knowledge in nanomaterials and their synthesis		**Syllabus Version**		**2021-2022**	
L= Lecture, T= Tutorial, P- Practical, C= Credits						

Course Objectives

1. Familiarize students the importance of nanomaterials for sustainable development.
2. Enhancing the student's knowledge on nanomaterials for environmental remediation.
3. Understand the photocatalysis reactions for solar fuel generation.
4. Apply the knowledge gained for developing efficient nanostructured photocatalysts.

Course Outcomes

1. Understand the benefits of nanomaterials for sustainable development (K2)
2. Analyze the concepts of photocatalysis and its technological significance. (K4)
3. Apply the photocatalysis reaction mechanisms towards contaminant degradation, hydrogen evolution and carbon dioxide reduction. (K3)
4. Create strategies for developing efficient nanostructured photocatalysts.(K6)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Photocatalysis**	**20 Hours**

Introduction; Light and matter interaction; Principles of Photocatalysis; Electronic band structure of semiconductors; Mechanisms of charge formation, separation and transfer; Basic principles of photocatalytic water splitting for hydrogen generation; Basic principles of photocatalytic reduction of CO_2; Photocatalysis surface and active species.

UNIT-II	**Environmental Remediation**	**16 Hours**

Introduction; Fabrication of nanostructured photocatalysts; Methods of improving photocatalytic activity: Design parameters; Photodegradation of dyes; Photodegradation of persistent organic pollutants; Photodegradation of Inorganic pollutants; Photodegradation of emerging contaminants; Photodegradation of gaseous pollutants; Characterization and analysis of acquired data.

UNIT-III	**Hydrogen Evolution and Carbondioxide Reduction**	**16 Hours**

Introduction; Electronic band structure considerations; Photocatalytic reaction mechanism and charge transfer; Fabrication of nanostructured photocatalysts and design parameters: H_2 generation and CO_2 reduction; Z-scheme heterojunction photocatalysts; Quantification and calculation of efficiency; Characterization

UNIT-IV	**Strategies for Improving Performance of Photocatalysts**	**15 Hours**

Introduction; Issues related to single-component photocatalysts; Microstructure modulation; Influence of facet and defects; Integration of noble metal nanostructures; Carbonaceous materials compounding – rGO, CNTs, CQDs; Integration with other semiconductor nanostructures.

UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**
Text Books/References		

1. Gianluca Li Puma, Detlef W. Bahnemann, Dionysios D. Dionysiou, Jinhua Ye and Jenny Schneider, Photocatalysis: Fundamentals and Perspectives, Publisher: Royal Society of Chemistry, ISBN: 9781782620419, 1782620419.
2. Umar Ibrahim Gaya, Heterogeneous Photocatalysis Using Inorganic Semiconductor Solids, Publisher: Springer Netherlands, ISBN: 9789400777750, 9400777752
3. Kazuya Nakata and Akira Fujishima, TiO_2 photocatalysis: Design and applications, Journal of Photochemistry and Photobiology C: Photochemistry Reviews 2012, 13, 169-189, https://doi.org/10.1016/j.jphotochemrev.2012.06.001
4. Chunping Xu, Prasaanth Ravi Anusuyadevi, Cyril Aymonier, Rafael Luque and Samuel Marre, Nanostructured materials for photocatalysis, Chemical Society Reviews, 2019,48, 3868-3902, https://doi.org/10.1039/C9CS00102F

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	M	L	M	S	M
CO2	M	L	L	M	M
CO3	L	M	S	S	L
CO4	M	S	S	S	S
S - Strong		M- Medium		L- Low	

Course Code	**NST.304-D**	**MICRO/NANO ELECTRO MECHANICAL SYSTEMS (MEMS/NEMS)**	**L**	**T**	**P**	**C**
Elective			**4**	**0**	**0**	**4**
Pre-requisite	Basic knowledge in nanoscience and nanodevices		**Syllabus Version**		**2021-2022**	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Understand an overview of MEMS and NEMS
2. Understand different fabrication methods of MEMS/NEMS
3. Identify the applications of MEMS/NEMS
4. Understand different characterization tools of MEMS/NEMS

Course Outcomes

1. Understand the basics and working principles of MEMS/NEMS (K2)
2. Recognize different application potential of MEMS/NEMS (K2)
3. Evaluate the quality of MEMS/NEMS using different characterization tools (K5)
4. Understand the Cross-disciplinary application of MEMS and NEMS (K2)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**MEMS Fabrication**	**18 Hours**
Overview of micro electro mechanical devices and technologies. Introduction to architecture design, Process flow, Fabrication, Packaging and testing. MEMS Fabrication, Deposition, lithography, and etching, Surface micromachining, Bulk micromachining, Bonding technologies, LIGA technology and related fabrication methods		
UNIT-II	**Applications of MEMS**	**18 Hours**
MEMS device concepts (micro sensors/actuators), Use of capacitive, Inductive, Optical, piezoresistive, Piezoelectric methods for sensing. MEMS Applications, Accelerometers and gyros, Pressure sensors, Micro optics, etc. Microsystems Packaging		
UNIT-III	**MEMS/NEMS Characterization**	**15 Hours**
Introduction to existing and next-generation metrology tools for MEMS and NEMS inspection and qualification. Theoretical principles of metrology and experimental work on characterization of prototype MEMS and NEMS devices.		
UNIT-IV	**Biological Applications of MEMS/NEMS**	**16 Hours**
Cross-disciplinary application of MEMS and NEMS to the biological sciences. Interaction of living cells/tissues with nanofabricated structures, Microfluidics for the movement and control of solutions - the development of I/O architectures for efficient readout of bioreactions.		
UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**

Text Books/References

1. Mohamed Gad – el – Hak, "The MEMS Handbook", Second Edition, CRC Press, 2005.
2. James J. Allen, "Micro Electro Mechanical System Design", CRC, 2005.
3. K. Subramanian, "Micro Electro Mechanical Systems: A Design Approach", Springer, 2008.
4. Tai-Ran Hsu, MEMS and Microsystems- Design, Manufacture and Nanoscale Engineering, John Wiley & Sons, INC. 2008. **ISBN:** 978-0-470-08301-7.

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	L	M	S	L	M
CO2	M	M	S	S	M
CO3	M	L	S	M	M
CO4	M	L	S	S	S
S - Strong		M- Medium		L- Low	

Course Code	NST.304-E	SUSTAINABLE NANOMATERIALS	L	T	P	C
Elective			**4**	**0**	**0**	**4**
Pre-requisite	Basic knowledge on nanomaterials		**Syllabus Version**		**2021-2022**	

L= Lecture, T= Tutorial, P- Practical, C= Credits

Course Objectives

1. Understand the toxicity of nanomaterials
2. Aware of environmental pollution act and importance of Green Chemistry
3. Understand different green synthetic approaches for the nanomaterial
4. Understand the environmental applications of nanomaterials

Course Outcomes

1. Understand the environmental pollution and could recognize the nanomaterial toxicity (K2,K1)
2. Understand the importance of Green Chemistry (K2)
3. Apply different green synthesis approach for the materials preparation (K3)
4. Apply the nanomaterials for environmental protection (K3)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

UNIT-I	**Nanomaterials Toxicity**	**18 Hours**
Environmental pollution and hazards: Toxicity of chemicals and their characterization, R&S Numbers, material safety data sheet (MSDS), highly toxic nanomaterials.		
UNIT-II	**Principle of Green Chemistry**	**18 Hours**
Environmental Pollution content Act (USEPA) 1990, Green chemistry, 12 principle of green chemistry, atom economy, alternative solvents, renewable materials, etc.		
UNIT-III	**Green Synthesis of Nanomaterials**	**15 Hours**
Green methods for nanomaterial synthesis, use of supercritical carbon dioxide, ionic liquids, RESS process, use of green reagents (citrate and glucose based synthesis of metal nanoparticles) biosynthesis of nanostructures, template-free synthesis of mesoporous silica and metal oxide		
UNIT-IV	**Environmental Applications of Nanomaterials**	**16 Hours**
Environmental application of nanomaterials. Water purification system, systems for harvesting solar energy, mesoporous materials for naked eye detection of toxic metal ions in water (mesosporous silica) self –cleaning materials, non-wetting glasses, super hydrophobic coatings etc.		
UNIT-V	**Contemporary Issues**	**5 Hrs.**
Expert lectures, General Seminars, online seminars – webinars		
	Total Lecture Hours	**72 Hours**

Text Books/References

1. Paul T. Anastas and John C. Warner, Green Chemistry : Theory and Practice, Oxford University Press (2000)

2. Paul M. Matlack, Introduction to Green Chemistry, CRC Press, 2nd ed. (2010)
3. Geoffrey B. Smith, Green Nanotechnology: Solutions for Sustainability and Energy in the Built Environment, CRC Press (2010)
4. P. Raveendran, Jie Fu & S.L. Wallen. Completely "green" synthesis and stabilization of metal nanoparticles. J.Am.Chem.Soc.(2003), 125, 13940-41.

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	M	M	S	S	M
CO2	L	M	S	S	S
CO3	L	S	S	M	M
CO4	L	M	S	S	S
S - Strong		M- Medium		L- Low	

Course Code	**NST.305**	**MINI PROJECT**	**L**	**T**	**P**	**C**
Project			**0**	**0**	**6**	**6**
Pre-requisite	Basic knowledge on nanoscience and nanomaterials		**Syllabus Version**		**2021-2022**	
L= Lecture, T= Tutorial, P- Practical, C= Credits						

Course Objectives

1. Inculcate and improve the research attitude of the student
2. To understand the process of literature review and use of online research resources
3. Train to design a research problem and to understand how to fix the objectives and methodologies to solve the problem
4. Documentation practices and improvement of communication and presentation skills

Course Outcomes

1. Apply the scientific concepts to identify and design a research problem in the area of nanoscience (K3)
2. Understand and analyze the results or data obtained from experiments or simulation (K2,K4)
3. Create problem solving skills with critical thinking, analytical reasoning and improved communication skills (K6)
4. Understand the documentation procedure for project report writing and aware of the importance of plagiarism check (K2)

K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create

Mapping with Program Outcomes

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	S	M	M	M
CO2	S	S	S	S	S
CO3	M	M	S	S	S
CO4	L	L	S	S	S
S - Strong		M- Medium		L- Low	

FOURTH SEMESTER

<table>
<tr><td>Course Code</td><td>NST.401</td><td rowspan="2">MAJOR PROJECT</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td colspan="2">Project</td><td>0</td><td>0</td><td>20</td><td>20</td></tr>
<tr><td>Pre-requisite</td><td colspan="2">Basic knowledge on nanoscience and nanomaterials</td><td colspan="2">Syllabus Version</td><td colspan="2">2021-2022</td></tr>
<tr><td colspan="7">L= Lecture, T= Tutorial, P- Practical, C= Credits</td></tr>
<tr><td colspan="7">Course Objectives</td></tr>
<tr><td colspan="7">1. Inculcate and improve the research attitude of the student
2. To understand the process of literature review and use of online research resources
3. Train to design a research problem and to understand how to fix the objectives and methodologies to solve the problem
4. Documentation practices and improvement of communication and presentation skills</td></tr>
<tr><td colspan="7">Course Outcomes</td></tr>
<tr><td colspan="7">1. Apply the scientific concepts to identify and design a research problem in the area of nanoscience (K3)
2. Understand and analyze the results or data obtained from experiments or simulation using data analysis softwares (K2,K4)
3. Apply the theoretical knowledge to explain the data collected from different advanced characterization techniques (K3)
4. Understand the importance of documentation procedure and research publication. (K2)</td></tr>
<tr><td colspan="7">K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create</td></tr>
<tr><td></td><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td colspan="7"></td></tr>
</table>

<u>Mapping with Program Outcomes</u>

Course Outcomes	Program Outcomes				
	PO1	PO2	PO3	PO4	PO5
CO1	S	S	M	M	M
CO2	S	S	S	S	S
CO3	M	M	S	S	S
CO4	L	L	S	S	S
S - Strong		M- Medium		L- Low	